

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant : Gary Jorgensen et al.

Serial No. : 09/762,719

Filing Date: February 9, 2001

Title: A DURABLE CORROSION AND  
ULTRAVIOLET-RESISTANT SILVER MIRROR )



) NREL 97-33

)

)

) Group Art: 2872

) Examiner: Audrey Y. Chang

)

)

AFFIDAVIT

I, Gary Jorgensen, hereby depose and say:

That I received a B.S. in Physics from Seton Hall University, South Orange, NJ in 1972;

That I received a M.S. in Physics from the University of Colorado, Boulder, CO in 1975;

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That from 1978-1985, I worked as a Senior Physicist at the Solar Energy Research Institute,  
Golden, CO.;

That from 1985-1987, I worked as a Senior Engineer at Melles Griot Diode Laser Division, Boulder, CO.;

That from 1987 to the present, I have been employed at the National Renewable Energy Laboratory, Golden, CO., as a Senior Scientist II;

That I was a Task Leader of Advanced Materials Development Activity within DOE's Concentrating Solar Power Program and Task Leader of Electrochromic Windows Durability Testing Project for DOE's Building Program; and that my responsibilities included overseeing a number of durability testing programs including laboratory accelerated exposure testing and an international network of outdoor exposure test sites. That I am also leader of Solar Glazings and High Temperature Absorber Development and Durability Testing;

That I have over 20 years experience in structural and thermal analysis, mechanical testing, and reliability testing of materials and devices;

That I received NREL's Outstanding Performance Award in February 1984, and have over 50 publications, three patents, and three pending patent applications;

That I am a member of the American Solar Energy Society and the American Society for Testing and Materials (ASTM); and

That my relevant publications are: Jorgensen, G., Bingham, C., Netter, J., Goggin, R., and Lewandowski, A., "*A Unique Facility for Ultra-Accelerated Natural Sunlight Exposure Testing of Materials*," *Service Life Prediction of Organic Coatings, A Systems Approach*, ACS Symposium Series 722, David R. Bauer and Jonathan W. Martin, Eds., American Chemical Society, Oxford University Press, 1999, pp. 170-185.

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That from 1979 to 1983 I was employed as a staff engineer at the Solar Research Institute in Golden, CO where I specialized in engineering analysis of optical materials and systems, development of solar thermal system performance prediction tools, and analysis, research and development of advanced solar concentrators and components;

That from 1983-1999 I co-founded and become co-president of Industrial Solar Technology (IST) in Golden, CO, wherein IST manufactured and installed parabolic trough solar systems for commercial and industrial applications. As a principal of a small business, my responsibilities included business development, project management, production engineering , economic analysis, and research and development; and

That from 1999 until the present I have been employed as a senior mechanical engineer at Solargenix Energy in Raleigh, NC with responsibility for mechanical design, system-level engineering design, and solar system performance analysis. I further provide optical and thermal design and analysis, advanced component research and development, new project development, economic analysis, and project management.

That we are co-inventors of U.S. Patent Application Serial No. 09/762,719.

That we have reviewed the Official Action dated December 17, 2003 which rejected the claims in said Application;

That we have reviewed the Patents of Roche et al., Schissel et al. and Sugisaki et al.;

That, upon comparison of the teachings of the silver mirrors and electrostatic recording material of these patents compared to the silver mirror of the application, it is clear that the present invention is an unobvious advance over Roche et al in view of Schissel et al. combined or Roche et al. in view of Schissel et al. further in view of Sugisaki, and that the manner in which the present invention silver mirror is superior to that of these patents are hereinafter set forth.

### **BACKGROUND**

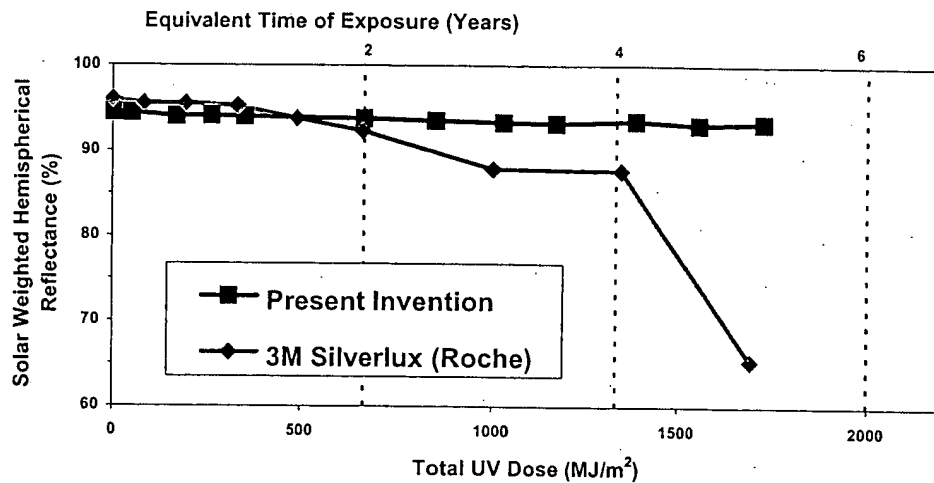
In about July of 1997 The National Renewable Energy Laboratory (NREL) had been leading a national effort for about 15 years to develop a viable silvered polymer solar mirror. Co-inventors Jorgensen and King were employed by NREL. Industrial Solar Technology (IST) had been installing solar concentrator energy generating systems for about the same time frame. Co-inventor Gee was employed by IST. The IST system used commercially available silvered polymer reflectors that exhibited limited durability during field service. The 3M Company was the major supplier of commercial products; two constructions were that of Roche et al. (PN. 4,645,714) [1] known as Silverlux, and a silvered polymethyl methacrylate (PMMA, an acrylic) film having a thickness of ~3.5 mils known as ECP-305. Exposure to two weathering variables

(moisture and the ultraviolet (UV) part of the solar spectrum) severely limited the outdoor use of these products [2]. Furthermore, the 3M Company was considering discontinuing their ECP-305 product (which in fact occurred soon thereafter).

The inventors of the present application had found that the Roche et al. construction alone (Silverlux) was not suitable for real-world solar applications. Under outdoor UV exposure, this material lost solar reflectance at an unacceptable rate. The level of UV screening provided by the UV absorbers incorporated into this construction was not adequate to protect the silver/acrylic co-polymer interface; this is because the thickness of the screening layer was too thin.

Insufficient UV screening is a fundamental limitation of the flood coating process inherent in the Roche et al. patent since flood coated layers are too thin to provide adequate UV screening. Additional/increased UV screening was required to make this material usable in solar applications; such a thicker UV screening layer could not be achieved by the Roche et al., process. Figure A shows the unexpected and superior difference in optical durability between the Roche et al. construction and our improved invention, wherein a thicker UV screening layer is affixed to the base Silverlux material. The abscissa corresponds to the cumulative UV dose by samples exposed outdoors in Golden, CO; 333 MJ/m<sup>2</sup> corresponds to about one year equivalent outdoor exposure. The ordinate is the measured spectral hemispherical reflectance convoluted with a terrestrial solar spectrum; this indicates the % of incident sunlight that a sample is capable of reflecting after a given exposure to UV light. As can be seen in Figure A, the Roche et al. construction degrades rapidly after 2-4 years exposure. This short useful life is unacceptable for solar applications which require a durability of at least 10 years. Our new construction clearly demonstrates superior performance relative to Roche et al.

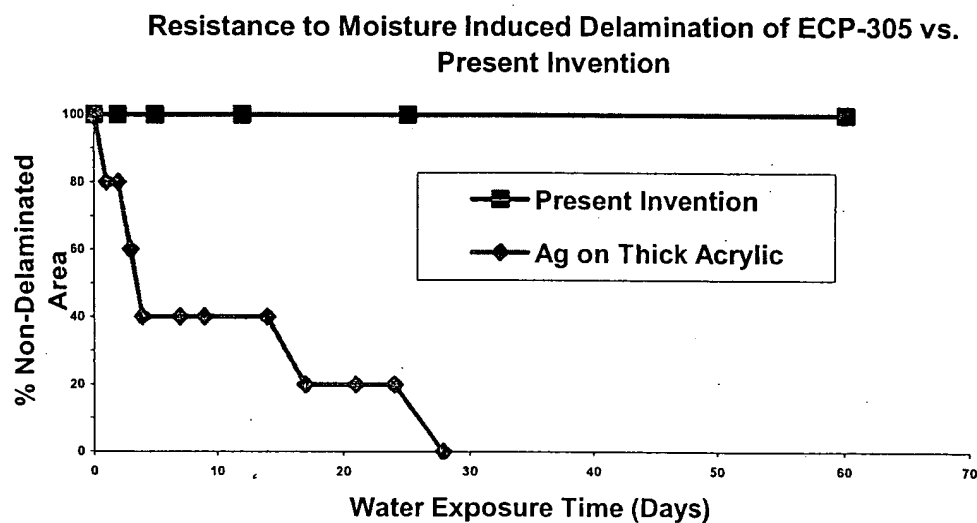
## Outdoor (Golden, CO) UV Durability of Roche Construction vs. Present Invention



**Figure A**

The addition of a thicker UV screening polymer film was neither an inconsequential nor an obvious matter. NREL and the 3M Company had previously collaboratively pursued application of a thick (~3.5 mils) acrylic film to a silvered polymer (e.g., polyethylene terephthalate, PET) substrate using a large number of candidate optical adhesives. These efforts included attempts to compound/incorporate various UV absorber packages into the adhesive layer. It should be noted that the 3M Company is considered a world expert in adhesive technologies. None of the candidate constructions were successful; they all yellowed under weathering exposure. It was unclear whether the discoloration was within the adhesive layer or at the adhesive/silver interface. By using an adhesive to affix a thick UV screening polymer film to a silvered PET substrate having a thin polymer overcoat (the 3M Silverlux product) the new construction prevents degradative interactions between the adhesive and the silver layer. This is the major innovation of the present invention.

Another deficiency of the prior art was related to constructions in which silvered thick acrylic films were specified. The inherent adhesion of vacuum-deposited silver with an acrylic film is poor. Upon exposure to moisture during outdoor service, solar mirrors that incorporate a silver/acrylic construction were found to be particularly susceptible to a failure mode known as tunneling wherein the silver layer catastrophically delaminates from the base acrylic film. The thick acrylic film absorbs moisture and swells, producing mechanical stresses that induce delamination with the silver layer. This effect is shown explicitly in Figure B. These results are for tests in which candidate silvered polymer solar mirror constructions are immersed in water and the % of delaminated area is measured as a function of length of immersion time. For samples of silvered thick acrylic films as specified in the cited prior art, 60% of the mirror surfaces had delaminated after only 4 days. This constitutes complete and unacceptable failure.



**Figure B**

Schissel et al. (PN. 5,361,172) [3] only teach how to improve the adhesion between a

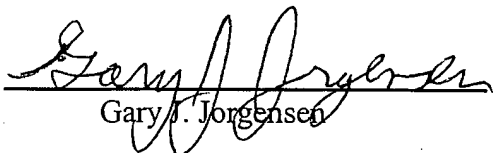
superstrate polymer film and a reflective silver layer by interposing a vacuum-deposited metal-oxide coating. This patent also teaches how to improve the corrosion resistance of the reflective silver layer by vacuum deposition of copper behind (i.e., after the silver is deposited onto the polymer film + metal oxide superstrate) the silver.

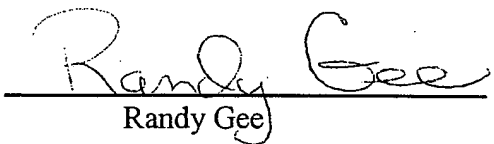
The present invention circumvents, in an economically viable manner, delamination problems and concerns by eliminating silvered thick acrylic from the construction. The silver reflective layer is deposited onto an alternate polymer film substrate such as PET. Silver demonstrates adequate adhesion to PET. An inexpensive (relative to vacuum deposition of metal oxide coatings) thin flood-coated layer of acrylic (that further may contain optional adhesion-promoting additives) also exhibits requisite adhesion to silver. Such a layer also provides a barrier between the corrosion-prone silver reflective layer and an externally-applied UV-screening film. Figure B confirms that the improved construction of the present invention results in extraordinary resistance to delamination. After over 60 days of water immersion, the preferred construction demonstrates 100% avoidance of failure.

Sugisaki et al. (PN. 5,681,642) is clearly non-related art and only makes transitory reference to the desirability for the use of a UV-absorptive film but neither explains nor elaborates why this is important or even relevant - nor the consequences of its exclusion. The existence of UV-absorptive polymer films has been well known for many years outside the patent literature. Usually, UV absorbers are added to polymer resins during processing (for example, the extrusion of film forms) as an attempt to provide UV resistance to the resulting polymer films themselves. Depending upon the base resin, this approach has been marginally successful. While the addition of UV absorbers can provide protection to the bulk material, if the polymer itself is not inherently



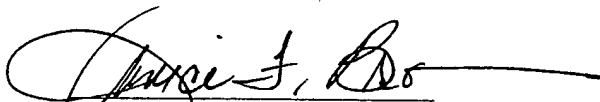
UV-resistant then degravative interactions will occur at the front surface where the UV absorbers do not provide adequate coverage. The present invention requires the use of such a material as an external UV screening element for otherwise UV-susceptible materials downstream of incident sunlight.

  
Gary J. Jorgensen

  
Randy Gee

(Affiant)

Sworn to and subscribed before me this 1st day of March, 2004.

  
Janice F. Brown, Notary Public  
My Commission expires: December 12, 2006

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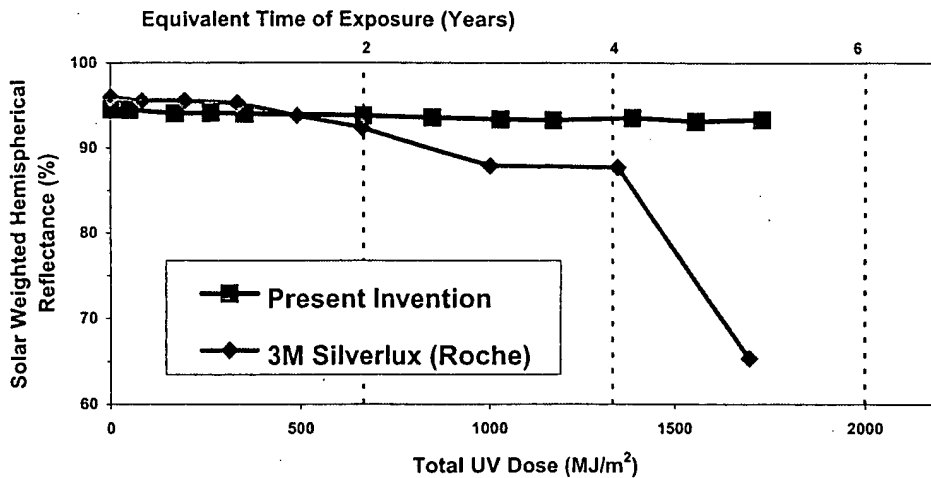
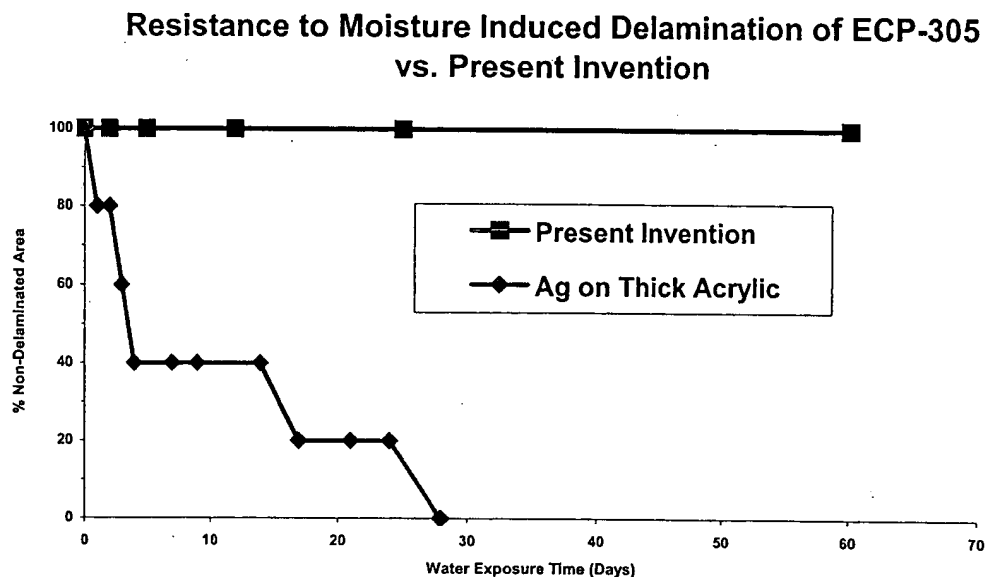


Figure A

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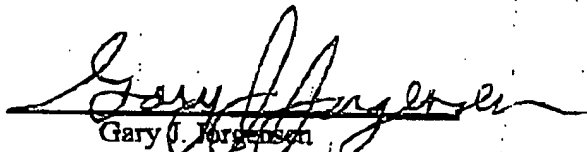
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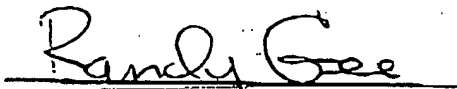
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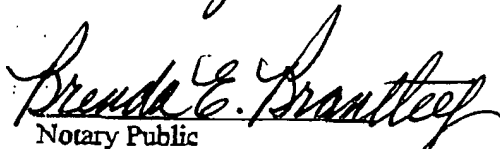
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Gary J. Jorgensen

  
Randy Gee

(Affiant)

Sworn to and subscribed before me this 15<sup>th</sup> day of June, 2004.

  
Notary Public  
My Commission expires:

**Brenda E. Brantley**  
Notary Public  
State of Colorado  
My Commission Expires 10/4/2005